ORIGINAL RESEARCH

Fracture Resistance of Endodontically Treated Tooth Restored with Fiber Reinforced Composite Core and Crown at Different Heights of Ferrule

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Abstract

Aims: The aim of this study was to compare the fracture resistance of endodontically treated teeth restored with fiber-reinforced composite core and crown using different postmaterials at different ferrule heights.

Materials and methods: A total of 49 extracted single-rooted lower premolar teeth were grouped into control (sound teeth), prefabricated fiber posts—IA (no ferrule), IB (2 mm ferrule), IC (3 mm ferrule), and prefabricated metal posts—IIA (no ferrule), IIB (2 mm ferrule), IIC (3 mm ferrule), with seven teeth for each group. After root canal treatment, posts were cemented, fiber-reinforced composite cores were built-up, and then metal crowns were cemented. Teeth were subjected to thermal cycling and compressive load until fracture.

Results: The control group exhibited the highest mean [standard deviation (SD)] fracture resistance [1041.31N (± 278.40)]. For comparison of the mean fracture resistance between fiber and metal posts at different heights of ferrule restored with fiber-reinforced composite cores, a significant difference was observed at 0 mm ferrule ($p = 0.003$). The association between fracture mode and types of prefabricated post was significant at 0 mm ferrule ($p = 0.026$). All teeth in fiber posts group had favorable fracture mode.

Conclusion: In the presence of ferrule, the fracture resistance of endodontically restored teeth with fiber posts and fiber-reinforced composite cores was comparable to those restored with metal posts. The favorable fracture mode occurred in teeth restored with fiber posts and fiber-reinforced composite cores, either with or without the ferrule.

Clinical significance: The fiber-reinforced composite cores increased the fracture resistance of tooth restored using fiber post with the presence of ferrule and resulted in favorable fracture mode in teeth with or without the ferrule. In the clinical situation, this material has the potential to be used for a core material in combination with the use of fiber posts for endodontically teeth with compromised coronal tooth structure.

Keywords: Ferrule, Fiber post, Fiber-reinforced composite, Fracture resistance, Metal post.

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Introduction

The fracture resistance of the teeth after a root canal treatment depends on the amount of the remaining tooth structure, height of ferrule, position of the tooth in the oral cavity, and different types of post and core.[1–4] Among all of the above factors, the height of a ferrule has significantly increased the fracture resistance of root canal-treated teeth.[5,6] A dental ferrule is the embracement of the tooth structure by a crown restoration at a required height prepared by a shoulder margin and parallel to coronal dentin walls.[7] An adequate amount of ferrule height is required to significantly withstand the fracture load, and it has been suggested that the minimum ferrule height should be 2 mm.[8,9]

After the root canal treatment, the post and core are placed in the tooth with an inadequate tooth structure to support the remaining coronal tooth structure.[10,11] The materials used for the post and core build-up should have adequate strength and resistance to ensure a successful restoration outcome.[12–14] Several materials are available for the core build-up, but the composite core possesses the highest compressive and flexural strength in comparison to amalgam and glass ionomer cement.[15] To date, previous studies have reported several successful outcomes on the survival of the teeth restored with the post, core, and crown. It has been reported that after following up on 41 cases of fiber posts and 46 cases of metal posts (titanium) for up to 132 months, the survival rate of teeth cemented with fiber posts was 58.7%, whereas 74.2% for metal posts (titanium).[16]

Previous studies have documented the introduction of a composite resin employed for dental restoration, everX Posterior (GC, Europe), which is a short fiber-reinforced composite.[17,18]

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The areas exposed to high-stress levels, such as the molars, are the main sites where this type of composite resin is utilized. Previous studies revealed significant improvements in some mechanical properties, such as flexural strength, load-bearing capacity, and fracture toughness, following the application of composite resin for dental restoration.[18–20] For instance, the utilization of short E-glass fiber fillers in reinforcing dental composite resin led to improved mechanical properties when compared to the conventional composite resin incorporated with particulate fillers.[18–21] Additionally, less polymerization shrinkage stress was exhibited by the short fiber reinforced composite resin in comparison to the conventional particulate filler restorative composite resins.[18]

Another important factor related to resistance is the failure mode. Schwartz and Robbins reported that failure mode could be affected by factors such as the ferrule effect, type of core material, and type of post in terms of flexibility.[22] Failure mode can be categorized as favorable or unfavorable. The favorable and restorable fractures include minor and moderate fractures, where the fractures were either restricted to the coronal portion or extended to the cervical portions of the tooth. Meanwhile, the unfavorable or unrestorable failure modes are contributed by the main fracture pattern arising from severe oblique or horizontal fractures of the crown and involve the structure of the root.[23]

Garoushi et al. discovered an improvement in the strength and fracture pattern of posterior composite restoration when a short-fiber reinforced composite named; everX Posterior (GC, Europe) was used under conventional composite.[24] The good physical properties of everX Posterior make it a suitable core material build-up in root canal-treated teeth and is recommended in high load-bearing areas. Hence, this study aims to (1) investigate the influence of ferrule on the fracture resistance of metal and fiber postretained restorations following the usage of short-fiber reinforced composite as the core material and (2) to determine the association between the fracture mode and different prefabricated posts at different ferrule heights. In this study, the endodontically treated teeth restored with prefabricated fiber posts and metal posts prepared with a ferrule at 0, 2, and 3 mm were assessed.

Materials and Methods

Study Location and Ethical Approval

This experimental study was performed at the Craniofacial Laboratory, School of Dental Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia. The ethical approval was obtained from Universiti Sains Malaysia Research and Ethics Committee (Ref. no USM/JEPeM/15070251).

Sample Size Calculation

The PS software (Dupont and Plummer, 1997) was used to calculate the sample size. SD of fracture resistance was estimated as 87 N based on a previous study.[25] In order to detect the difference of 152 N of fracture resistance with 80% power and α 0.05, six samples were needed in each group. With the anticipation of 10% failure during sample preparation, the sample size for each group would be seven. There were seven groups in this study; therefore total sample size in this study was 49.

Teeth Collection, Inclusion and Exclusion Criteria

Table 1 depicts the materials employed in this study. A total of 49 human mandibular teeth were collected. The inclusion criteria were straight single-rooted premolars teeth extracted due to periodontal problems or orthodontic treatment. Meanwhile, teeth with dental caries, cracks and defects, curved, and those with previous root canal treatment, post, and crown were excluded from this study.

Teeth Standardization, Cleaning, Disinfection, and Grouping

The teeth were measured and standardized with mesiodistal and buccolingual dimensions of ± 10% and a root length of 15 ± 1 mm using a digital caliper (Mitutoyo, Japan). The teeth were cleaned with an ultrasonic scale (Piezon system, Electro Medical Systems, and Switzerland) and inspected for minor cracks using a stereomicroscope (Zoom Stereomicroscope 9, Olympus, Japan). Furthermore, 10% formalin was applied to disinfect the teeth before storing them in distilled water. The teeth were then divided randomly into seven groups comprising seven teeth in each group. All specimens were root canal treated except those in the control group. The control and experimental groups were as below:

- Control group: Sound teeth, no root canal treatment, no post, and core crown.
- Groups IA–C: Prefabricated fiber post, short fiber-reinforced composite core, and metal crown.
- Group IA: No ferrule.
- Group IB: 2 mm ferrule.
- Group IC: 3 mm ferrule.
- Groups IIA–C: Prefabricated metal post (titanium), short fiber-reinforced composite core, and metal crown.
- Group IIA: No ferrule.

Table 1: Materials that were used in the study

Brand	*Compositions*	*Manufacturer and country*	*Lot No.*
Parapost XP (P780)	Titanium post	Coltene Whaledent, United States of America	MT 108980
Parapost fiber white (PF160)	Unidirectional glass fiber/resin	Coltene Whaledent, United States of America	109573
RelyX U200	Silane-treated silica (55–65% by wt), substituted methacrylate, silane-treated silica, sodium p-toluene sulfonate, 1-benzyl L-5-phenyl L-barbic acid, calcium salt, and calcium hydroxide	3M ESPE, Germany	4388995
everX Posterior Composite resin	Inorganic filler 74.2 wt% and 53.6 vol% Short E-glass fiber filler, Barium glass Bis-GMA, and TEGDMA, Silicon dioxide, PMMA, and Photoinitiator	GC, Europe	1807302

Bis-GMA, bisphenol-A-glycidyl methacrylate; PMMA, poly(methyl methacrylate); TEGDMA, triethylene glycol dimethacrylate; vol %, volume percentage; wt%, weight percentage

- Group IIB: 2 mm ferrule.
- Group IIC: 3 mm ferrule.

Root Canal Preparation

The root canal was treated with a rotary system, namely X-Smart Motor with ProTaper Next System (Dentsply Maillefer, Switzerland), according to the manufacturer's guidelines. The working length was set at 1 mm from the radiographic apex. The root canal was prepared to master apical file size F3 (ProTaper Next System, Dentsply Maillefer, Switzerland). A gutta-percha and AH26 sealer (Dentsply Maillefer, United States of America) were used to obturate the canals. According to the experimental groups, a water-cooled hard tissue cutter (EXAKT Apparatebau, Germany) was used to cut the teeth perpendicular to the long axis of the tooth.

Postpreparation and Cementation Procedures

The gutta-percha was removed after storage in water for 24 hours at 37°C. Specifically, increasing sizes (2, 3, and 4) of Gates-Glidden burs were utilized to obtain the required length. Periapical radiographs were taken to ensure 5 mm gutta-percha remained at the apical area.

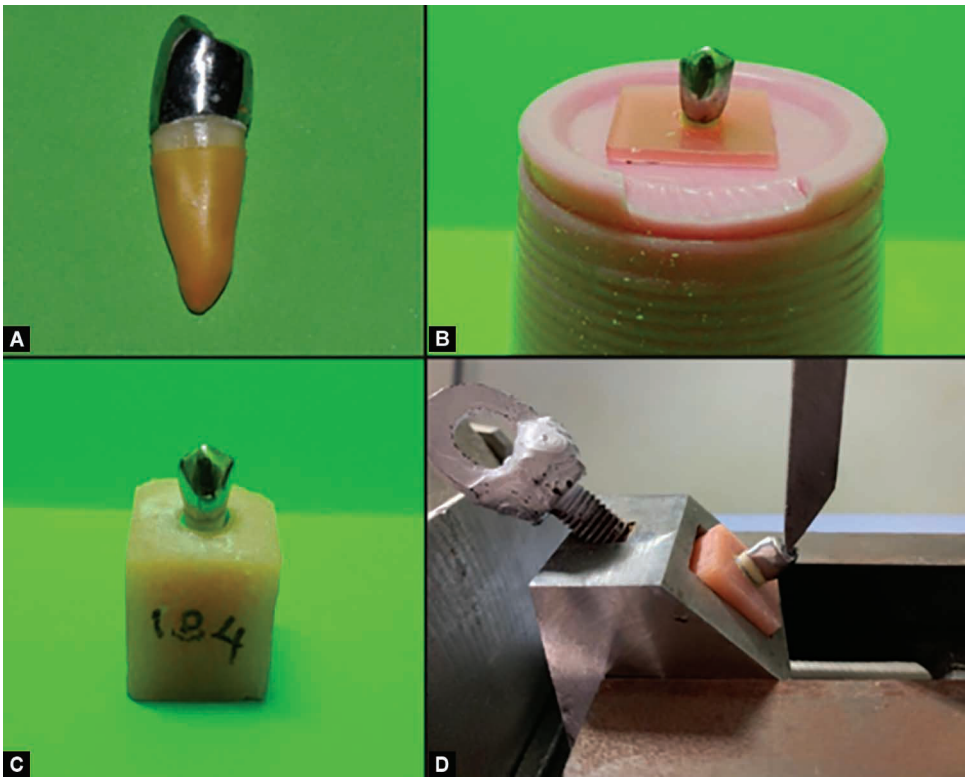
The postspace preparation was performed following the manufacturer's instructions with a post drill to achieve a postspace length of 10 mm for all teeth. For teeth in groups IA,IB, and IC, prefabricated fiber posts (Para Post Fiber White, Coltene Whaledent, United States of America) were cemented with resin cement RelyX U200 (3M ESPE, Germany) as described by the manufacturer. For teeth in groups IIA, IIB, and IIC, the prefabricated metal posts (Para Post XP Titanium, Coltene Whaledent, United States of America) were cemented using similar resin cement. Periapical radiographs were taken to assess the fitting of the post before cementation.

Core Build-up and Crown Preparation

Standardized cores of 5 mm height and 6°taper were fabricated with everX Posterior composite (GC, Europe) using standardized vacuum matrices. The core was polymerized from each side for 40 seconds. In this study, all the teeth were prepared for metal crown restoration. The impressions were constructed with light and heavy body polyvinyl siloxane (PVS) impression materials (Examix NDS, GC, United States of America), which were sent to the laboratory for crown construction. Metal crowns were cemented using RelyX U200 (3M ESPE, Germany).

Mounting of the Specimens and Periodontium Simulation

The techniques described by previous researchers were adopted with little modifications for the root mounting process.[26,27] A bone at a 2 mm level below the cementoenamel junction (CEJ) was simulated. All roots were embedded in the middle of a cold-cured acrylic block. Prior to the embedding process, all the root surfaces were inserted into melted wax to a depth of 2 mm below the facial CEJ. Resultantly, a layer ranging from 0.2 to 0.3 mm, which is approximately equal to the average thickness of the periodontal ligament, was produced (Fig. 1A). The teeth were then mounted in the acrylic blocks (Fig. 1B) and extracted upon observing the first indication of polymerization. Subsequently, the wax spacer was removed from the alveolus of the block and root surface. An injectable PVS impression material (Light body, Examix NDS, GC, United States of America) was introduced into the acrylic resin alveolus using a dispenser gun. The teeth were reinserted into



Figs 1A to D: (A) Application of 0.2–0.3 mm wax spacer before replacement by PVS impression material to simulate periodontal ligament; (B) Tooth was embedded in cold cure acrylic to simulate alveolar bone; (C) Tooth with PVS impression material to simulate periodontal ligament; (D) Specimens were placed under loading at a 45° angle to the long axis of the tooth

the test block. After the impression material was completely set, a scalpel blade was then used to remove any excess silicone material, thus creating a flat surface. Finally, the periodontal ligament was simulated by a thin layer of silicone material (Fig. 1C).

Thermal Cycling

The restored teeth for both groups were stored at room temperature in distilled water and subjected to thermal cycling (Automatic Thermo cyclic Dipping Machine, ATDM-T6ED-USM, Malaysia) of 600 cycles in a water bath (5–55°C) with a dwell and traveling time of 20 and 10 seconds, respectively.

Fracture Resistance Test

A universal material testing machine (Shimadzu, Japan) was used to perform a fracture resistance test on each specimen. The specimens were placed under loading at an angle of 45° to the long axis of the tooth (Fig. 1D). The application point was midway between the buccal cusp lingual slope and also between the cusp tip and central fissure. This test was performed using a 0.5 mm/minute crosshead speed.

Failure was considered either when the core material gave way by displacing from the post head or when the core or tooth was affected by a fracture. The load was measured in Newton (N). The failure mode was assessed with a stereo microscope (Zoom Stereomicroscope 9, Olympus, Japan).

Failures were classified as follows:

- Favorable: Comprising adhesive failures and crown fractures. Failure was considered favorable when the fracture line was above the simulated bone level.
- Unfavorable: This failure mode included the root fracture and was considered present when the fracture line was below the simulated bone level.

Statistical Analysis

All analyses were performed using the software package IBM Statistical Package for the Social Sciences version 24.0. The significant difference of fracture resistance for root canal-treated teeth restored with fiber and metal posts at different heights of ferrule was assessed using a one-way analysis of variance (ANOVA), and multiple comparisons *post hoc* tests (Sheffe's test) were carried out. Comparisons of the mean fracture resistance between the fiber and metal posts groups at 0, 2, and 3 mm ferrule were analyzed using an independent *t*-test. A Chi-squared (χ^2) test was used to assess the association between the fracture mode and different types of prefabricated posts (fiber and metal) using a short fiber-reinforced composite core and metal crown at different heights of the ferrule. Statistical significance was considered at $p < 0.05$.

Results

For comparison of fracture resistance of the control group and the root canal-treated teeth restored according to fiber and metal post at 0, 2, and 3 mm ferrule, the data were analyzed using a one-way ANOVA test (Table 2). From the table, it can be observed that the highest mean (SD) fracture resistance was found in the control group, which was 1041.31 (278.39) N. Among the fiber posts groups, the highest mean (SD) fracture resistance was observed for group IC (3 mm ferrule) [786.28(167.52) N], and group IA (0 mm ferrule) exhibited the lowest mean (SD) fracture resistance [304.31 (236.12) N]. There was a significant difference in mean fracture resistance between the groups ($p = 0.000$).

For the root canal-treated teeth restored with prefabricated metal posts, the highest mean (SD) fracture resistance was also noted in the control group, which was 1041.31(278.39) N. Among the metal posts groups, a similar finding was observed as in fiber post groups in which the highest mean (SD) fracture resistance was observed for group IIC (3 mm ferrule) [826.22 (387.62) N] and the group IIA (0 mm ferrule) exhibited the lowest mean (SD) fracture resistance [633.51 (192.01) N]. There was a significant difference in mean fracture resistance between the groups ($p = 0.017$).

For comparison of mean fracture resistance between prefabricated fibre and metal posts using short fiber-reinforced composite cores and metal crowns at 0, 2, and 3 mm ferrule, the significant difference between the groups was only observed at 0 mm ferrule ($p = 0.003$) (Table 3). At 0 and 2 mm ferrule, the fracture resistance of endodontically treated teeth with fiber posts was lower than those restored with metal posts. From Table 3, it was noted that at 3 mm ferrule, the teeth restored with fiber posts exhibited a higher fracture resistance as compared to the teeth cemented with a metal post. However, the result was not statistically significant.

Meanwhile, Table 4, depicts the association between fracture mode and different types of prefabricated posts (fiber and metal) using fiber-reinforced composite cores and metal crowns at 0, 2, and 3 mm ferrule, respectively. A significant association was observed only between groups IA and IIA ($p = 0.026$). The control group reflects the highest unfavorable fracture, which was below the simulated bone level (85.71%), whereas the lowest unfavorable fracture (0%) was observed in group IA (0 mm ferrule and fiber post).

Discussion

To date, the restoration of endodontically treated teeth remains a challenge to clinicians as the successful outcome of the treatment depends on several factors, such as the post and core materials,

Table 2: Comparison of fracture resistance for root canal treated teeth according to types of post (fiber and metal post) at different heights of ferrule

Groups	*n*	*Fracture resistance (N) mean (SD)*	*F statistic [degree of freedom (df)]*	*p-value*[a]
Control	7	1041.31 (278.39)	18.73	0.000*
IA (fiber post, 0 mm)	7	304.88 (236.12)	(3)	
IB (fiber post, 2 mm)	7	656.05 (128.18)		
IC (fiber post, 3 mm)	7	786.28 (167.52)		
Control	7	1041.31 (278.39)	4.149	0.017*
IIA (metal post, 0 mm)	7	633.51 (192.01)	(3)	
IIB (metal post, 2 mm)	7	708.43 (163.81)		
IIC (metal post, 3 mm)	6	719.214 (290.04)		

[a]One-way ANOVA test; *significant at $p < 0.05$; for teeth restored with fiber posts, multiple comparison *post hoc* test (Sheffe's test) showed significant differences between IA and IB ($p = 0.002$), IA vs IC ($p = 0.001$), IA vs control ($p = 0.000$) and IB vs control ($p = 0.008$) whereas, for those restored with metal post, multiple comparison *post hoc* test (Sheffe's test) showed significant differences only for control vs IIA ($p = 0.013$)

the types of luting agents, the definitive coronal restorations, the functional occlusal loads, the remaining tooth structure, and the structural change of dentin after the root canal treatment.[28–30]

Several studies have been conducted to find an ideal restoration for endodontically treated teeth; however, there was no consensus made.[30] A short fiber-reinforced composite was chosen in this study because this material was claimed to exhibit good physical properties and was recommended to be used in high load-bearing areas.[20]

Human-extracted teeth were used in this study to simulate the natural dentin properties in terms of bonding properties and fracture load. We used the extracted single-rooted mandibular premolars as these teeth were easy to collect and commonly had straight canals for standardization. The direction and position of the specimens' loading in this study were based on the recommendation by Wandscher et al.,[31] who claimed that the fracture resistance of root canal-treated teeth would be in the worst-case scenario when the teeth were subjected to the oblique load (45° to the long axis of the tooth).

A study by Al-Wahadni et al. reported that with the presence of 2 mm ferrule, a significantly higher mean (SD) fracture load [571.6N (± 80.3)] was recorded in the group of titanium posts compared to the teeth restored with glass fiber posts with the mean (SD) fracture load of 389.0 N (± 124.3).[32] Later, Makade et al. also found that the mean fracture resistance of the endodontically treated teeth restored with prefabricated metal posts (stainless steel) with 2 mm ferrule was higher than those restored with fiber posts; with the mean (SD) of 1270 N (± 100.4) and 1217 N (± 156.30), respectively.[33] These findings were similar to the present result for the teeth with 2 mm ferrule in which those in the metal post group exhibited a higher fracture resistance [708.43 N (± 163.81] than the teeth in the fiber post group [656.05 N (± 128.18)]. Nevertheless, no significant difference was detected between the two groups *($p = 0.518$).* In contrast, the presence of 3 mm ferrule reflected that the teeth restored with fiber posts demonstrated a higher mean (SD) fracture resistance [786.28 N (± 167.52)] than those restored with metal posts [719.21 N (± 290.24)] despite no significant difference between the groups ($p = 0.613$). This finding could be explained by the similar modulus of elasticity in the fiber posts and metal posts, which led to a better monoblock system with the tooth structure and the fiber-reinforced composite cores. The researchers concluded that an optimum bonding would facilitate an even distribution of the occlusal force transmission to the monoblock system.[34,35]

Apart from the height of the ferrule, the combination of the fiber post and the fiber-reinforced composite used as a core material in this study may contribute to the improved fracture resistance of endodontically treated teeth. A study by Alshabib et al. revealed that the fiber-reinforced composite (everX posterior, GC, Europe) recorded the highest fracture toughness relative to other tested composite materials.[36] The researchers argued that several reasons improved the resistance of the fiber-reinforced composite. Specifically, its longer fiber length facilitated the effective transfer of stress from the matrix and the thermoplastic poly(methyl methacrylate) (PMMA) chains, thereby reducing the stiffness of the bisphenol-A-glycidyl methacrylate (Bis-GMA) monomer.[36]

Table 3: Comparison of mean fracture resistance between prefabricated fiber and metal posts using short fiber-reinforced composite cores and metal crowns at 0, 2, and 3 mm ferrule

Ferrule height/groups	*Fracture resistance (N) mean (SD)*	*t-statistic (df)*	*p-value*[a]
Control group	1041.31 (278.40)		
0 mm IA (fiber post) IIA (metal post)	304.88 (236.12) 633.51 (192.01)	0.970 (12)	0.003*
2 mm IB (fiber post) IIB (metal post)	656.05 (128.18) 708.43 (163.81)	0.663 (12)	0.518
3 mm IC (fiber post) IIC (metal post)	786.28 (167.52) 719.214 (290.04)	2.602 (11)	0.613

[a]Independent *t*-test; *significant at $p < 0.05$

Table 4: Association between fracture mode and different types of prefabricated posts (fiber and metal) using short fiber reinforced composite cores and metal crowns at 0, 2, and 3 mm ferrule

	Fracture mode			
Groups	*Repairable (%)*	*Nonrepairable (%)*	*χ^2- stat (df)*	*p-value*[a]
Control	14.29	85.71		
0 mm ferrule IA (fiber posts) IIA (metal posts)	100 28.6	0 71.4	0.02 1	0.026*
2 mm ferrule IB (fiber posts) IIB (metal posts)	57.1 42.9	42.9 57.1	0.281 1	0.592
3 mm ferrule IC (fiber posts) IIC (metal posts)	51.7 28.6	42.9 71.4	0.292 1	0.589

[a]Chi-squared (χ^2) test; *significant at $p < 0.05$

Ferrari et al. discovered that the fiber posts failure was not associated with a nonrepairable fracture but was caused by postdebonding or endodontic failures.[34] The fracture strength of the endodontic teeth (lacking a remaining tooth structure) was not reinforced with the placement of a glass fiber post. Nevertheless, more cases of favorable failure types were observed in the combination of fiber post and adhesive restoration.[37] Later, Fráter et al. reported that there was an insignificant increase in fracture resistance for the teeth restored in molar teeth with a short fiber-reinforced composite, but a more favorable fracture mode was observed.[38] This was similar to the findings in the present study as no association was found between fracture mode and different types of prefabricated posts (fiber and metal) upon using short fiber-reinforced composite cores and metal crowns at 2 and 3 mm ferrule. A significant difference was only observed between the fiber posts groups and metal posts at 0 mm ferrule.

In the current study, the incidence of root fracture occurred in all groups apart from those restored with fiber posts at 0 mm ferrule. The teeth in the metal posts groups recorded a higher incidence of unfavorable fracture compared to those in the fiber posts groups at 0, 2, and 3 mm ferrule. In contrast, Lazari et al. reported that all the specimens, regardless of the types of posts, demonstrated an unfavorable fracture. The teeth were clinically indicated for extraction.[39]

A study by Torres-Sánchez et al. confirmed that the fracture mode in the teeth with 2 mm ferrule restored with fiber posts was more favorable compared to those teeth cemented with the metal posts.[40] The elastic modulus of fiber posts was closer to that of dentin, causing repairable fracture as less stress transmission on the rootled to the nonrepairable fracture when compared to the higher modulus elasticity for metal posts.[12,40–42] Additionally, the presence of ferrule would create a less stress distribution at postabutment and abutment-root interfaces, thereby resulting in more repairable fractures.[43] Barcellos et al. reported that most of the forces were absorbed by the fiber posts, thus reducing the stress on the root and resulting in less root fracture.[44] On the contrary, titanium posts have high rigidity and elastic modulus. Thus, the stress load, which was completely transmitted to the tooth, induced a root fracture.[45]

Limitations of the Study

This study was conducted in the laboratory, and the result was not applicable to clinical situations due to the limitations listed below:

- The loading tests were performed under static loading, which can only simulate a clenching load.
- The load was only applied in one direction. Different directions of loading and location of loading may affect the fracture resistance behavior.
- In this study, only one factor was considered, which was the ferrule height. Other factors, such as newly developed types of cement, posts, core materials, crowns, and ferrule configurations, would influence the fracture resistance of endodontically treated teeth. Furthermore, the influence of postadaptation to dentine and core material on fracture resistance was not considered in this study.

Conclusion

Conclusively, the mean fracture resistance between prefabricated fiber and metal posts using short fiber-reinforced composite cores and metal crowns were significantly different at 0 mm ferrule. The combination of fiber post and short fiber reinforced composite core resulted in a higher favorable failure type, especially in cases of the main structural tooth loss compared to those restored with a metal post.

Clinical Significance

The fiber-reinforced composite cores increased the fracture resistance of tooth restored using fiber post with the presence of ferrule and resulted in favorable fracture mode in teeth with or without the ferrule. In the clinical situation, this material has the potential to be used for a core material in combination with the use of fiber posts for endodontically teeth with compromised coronal tooth structure.

Acknowledgments

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